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CDF and D0

W $\rightarrow \tau\nu$ and Γ_W Studies at the Tevatron Collider

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CDF and D0 Collaborations
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Abstract

The most recent results on the studies of the W properties, namely of the process W$\rightarrow \tau\nu$ and of the Γ_W measurements performed in $\bar{p}p$ collisions at $\sqrt{s}$=1800 GeV, are reported. The data are from the two experiments operating at the Tevatron Collider, CDF and D0.

The Tevatron Collider producing $\bar{p}p$ collisions at $\sqrt{s}$ =1800 GeV gives the greatest and, up to the recent starting of the Lep2 operations, unique opportunity to study the W vector boson and its electroweak properties. The investigation of the process W$\rightarrow \tau\nu$ makes possible the direct measure of the τ coupling to the electroweak charged current and test the electroweak universality at $Q^2 \approx M^2{}_W$. The W boson width is a fundamental parameter well predicted in the standard model. The comparison of its measured experimental value with the standard model prediction is a good test to rule out additional non standard decay modes of the W. In this paper we present the most recent results obtained by the two experiments, CDF and D0, operating at the Tevatron Collider from the studies on the W$\rightarrow \tau\nu$ process and from the Γ_W measurements.

1 W$\rightarrow \tau\nu$

D0 presents a measurement of the W production cross section times the branching ratio $B(W \rightarrow \tau\ \nu)$, $\sigma(\bar{p}p \rightarrow W + X) \times B(W \rightarrow \tau\ \nu)$. This can be used with the corresponding result from the electron channel, $\sigma(\bar{p}p \rightarrow W + X) \times B(W \rightarrow e\ \nu)$, to get the ratio g_τ/g_e. The measure is based on an integrated luminosity of 16.84 pb^{-1} collected during run Ia and the τ lepton is identified through its hadronic decay modes. The signature for the W $\rightarrow \tau\nu, \tau \rightarrow \nu + hadrons$, is characterized by an isolated and very narrow hadronic jet with low multiplicity, accompanied by a large amount of missing energy, $\not{E}_t$. The selection starts with a trigger requiring $\not{E}_t\ >\ 16$ GeV, a leading narrow jet with $E_t > 20$ GeV, no other jet with $E_t\ >\ 15$ GeV within $140^o\ \div\ 220^o$ in ϕ of the leading jet, or within 30^o in ϕ of the $\not{E}_t$ direction. In the offline analysis further selection cuts are applied requiring leading jet $25 < E_t < 60$ GeV, jet width $W \leq 0.25$, at least one track in 0.1 radians in ϕ of the calorimeter cluster, a jet profile, $P \geq 0.55$, where $P = (E_{t1} + E_{t2})/E_t$, $\not{E}_t > 25$ GeV, no electron or muons with $E_t > 15$ GeV.

Misidentified τ signals are generated by the electronic noise in the calorimeter and by the underlying event. This effects are modeled with a Data-Based Monte Carlo (DBMC) and the extimated number of fake events subracted from the selected data sample. The physics background from $Z \rightarrow \tau\tau$ is studied using ISAJET Monte Carlo and the extimated contamination subracted. The dominant background coming from QCD events in which one

[1] Talk presented at the XIII Topical Conference on Hadron Collider Physics, Mumbai(India), January 14-20, 1999

of the jets mimics a τ jet, and jets that fluctuate so as to give $\not{E}_t$ is extracted from the data using the profile distribution. Comparison of the profile distribution for the data sample with the P distribution of a sample of data in which the P, $\not{E}_t$ and single jet cuts have been released, allows the estimation of the QCD background contamination. The acceptance is determined using ISAJET Monte Carlo and the efficiency is obtained appling the trigger requirements and the offline cuts to the DBMC events sample. The obtained result for the σ_W times the brancing ratio $B(W \to \tau\nu)$ is:

$$\sigma_W \times B(W \to \tau\nu) = 2.38 \pm 0.09 \pm 0.10 \pm 0.13 \text{ nb}$$

where the errors are statistical, systematic and luminosity, respectively. From the previous measurement of:

$$\sigma_W \times B(W \to e\nu) = 2.36 \pm 0.02 \pm 0.07 \pm 0.13 \text{ nb}$$

the following ratio of the coupling constants is computed:

$$g_\tau / g_e = 1.004 \pm 0.019(stat.) \pm 0.026(syst.)$$

CDF published a previous result on g_τ/g_e ($g_\tau/g_e = 0.97 \pm 0.07$) [1] using hadronic τ decay modes for τ identification. CDF has now preliminary results on the ratio g_τ/g_e from the channel W$\to \tau\nu$, $\tau \to e\nu\nu$. The impact parameter of the electron track coming from the τ decay measured in the Silicon Vertex Detector (SVX) is used for the τ identification. Run Ib data have been used, selecting events with a trigger requiring a central electron of $E_t \geq$ 12 GeV.
Additional requirements for the basic sample impose restrictions on:

- E/p, Had/EM, Strip-Track matching;
- SVX vertex quality;
- electron track to be associated to an SVX track.

The impact parameter (d_0) distribution of the SVX track associated to the electron in the τ signal sample is fitted to a sum of the three components: the d_0 distributions for the W$\to e\nu$ process, the W$\to \tau\nu, \tau \to e\nu\nu$ process, and the QCD background processes. The probability density function used in the likelihood calculation is defined by:

$$f(d_0; b, c) = a \cdot f_e(d_0) + b \cdot f_\tau(d_0) + c \cdot f_{BG}(d_0)$$

where a,b and c are event fraction and $f_e(d_0)$, $f_\tau(d_0)$ and $f_{BG}(d_0)$ are reference d_0 probability density function for the processes quoted above. $f_e(d_0)$ and $f_\tau(d_0)$ are obtained using a simple Monte Carlo simulation and $f_{BG}(d_0)$ is from the real data. Actually the fit is performed in two steps. First the events in 12 GeV $< E_t <$20 GeV are divided into four groups according to E_t and four independent fit are performed. Then a global fit is computed in which the background fraction (parameter c) is constrained as determined from an independent method of evaluation based on the data. In fig.1 the results for the fits in the four E_t intervals are shown together with the separeted contributions of the signal and the background. In fig.2 are shown the likelihood functions in the four E_t regions and the final combined likelihood. The final result is:

$$g_\tau / g_e = 1.01 \pm 0.17(stat.) \pm 0.09(syst.)$$

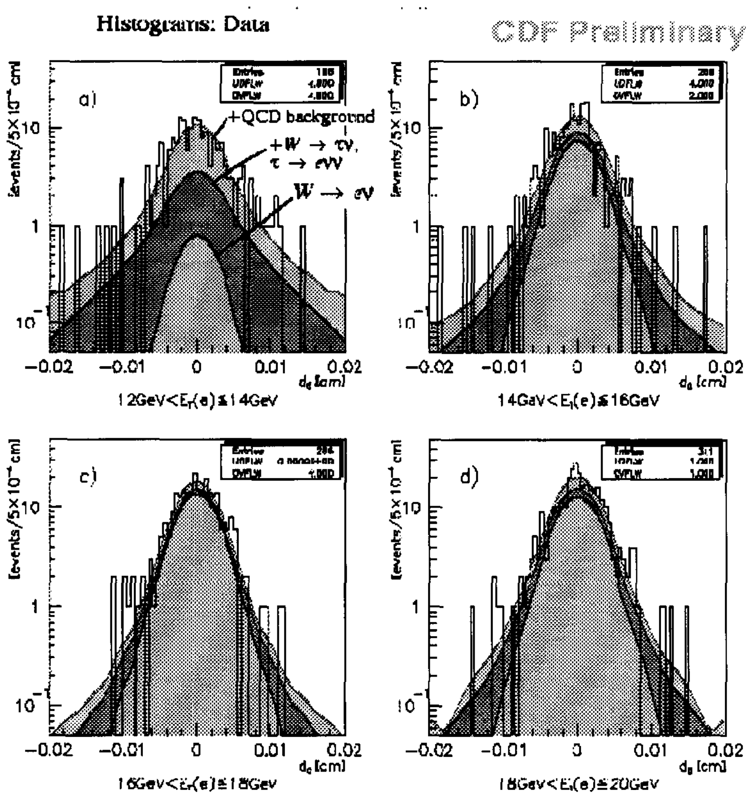

Figure 1: - The impact parameter distribution and the probabilty density function at the maximum likelihood estimate for the fit parameter in the four E_t regions. The solid histogram represents the data, the dot-dashed curve is W$\rightarrow e\nu$ reference function, the dotted is the sum of the W$\rightarrow e\nu$ and the W$\rightarrow \tau\nu, \tau \rightarrow e\nu\nu$, and the dashed is the total, including the background reference function.

1.1 W Charge Asymmetry in W$\rightarrow \tau\nu$

CDF has measured the W charge asymmetry in the W $\rightarrow \tau\nu$ channel. Preliminary results are based on an integrated luminosity of 15.7 pb^{-1} from run Ia. τ's are identified by the hadronic decay mode. The starting sample is collected with a trigger requiring:

- $\not{E}_t > 20$ GeV;
- a narrow cluster (less than 6 towers) with E$_t > 20$ GeV and with one track of p$_t > 5$ GeV pointing to it;
- no other cluster back-to-back to the leading cluster direction in 30^o.

Offline selection requires:

- $\not{E}_t \geq 20$ GeV, $\not{E}_t$ significance >2.4;
- jet E$_t > 20$ GeV with a seed track of p$_t > 5$ GeV pointing to it (within 10^o from cluster centroid);
- invariant mass of track-CES less than 1.8 GeV;
- 1-prong cluster with EM fraction greater than 0.1;
- no other jets with E$_t > 10$ GeV;

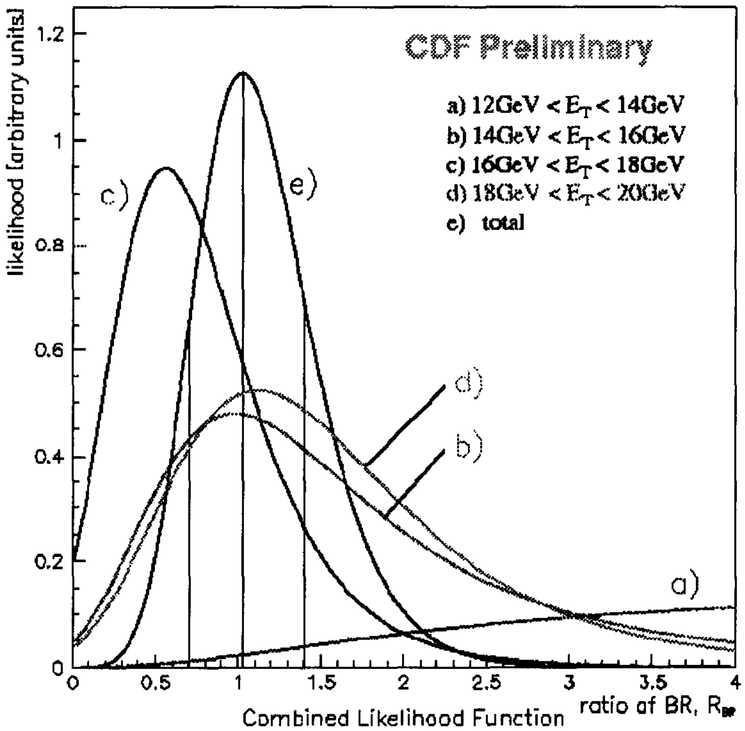

Figure 2: - The background constrained likelihood function in the four E_t regions, a) $12GeV < E_t < 14GeV$, b) $14GeV < E_t < 16GeV$, c) $16GeV < E_t < 18GeV$, d) $18GeV < E_t < 20GeV$, and e) the combined function are shown. The vertical bars indicate the maximum of the combined function and the negative and the positive errors points.

- no jets with $E_t > 5$ GeV back-to-back to the leading jet direction within 30^o;
- rejected electron and muon events.

The final sample is binned in three variables:

- the charge pattern index (the data are divided in 11 bins each one identifing a combination of the multiplicity and the total charge of the τ cluster);
- the η bins (the η interval -1.2 $\div$ 1.2 is divided in 8 bins);
- the isolated - non isolated samples (The data sample is divided in two subsample. Isolated: no track with $p_t > 1$ GeV in an annulus from 10-30^o around the jet direction.(This sample is $W \to \tau\nu$ rich); non isolated: the nearest track with $p_t > 1$ GeV in a 10-20^o annulus has also $p_t > 2$ GeV (QCD processes rich)).

A fit with the likelihood method is performed on the final distributions for the two samples. The resulting asymmetry is shown in fig.3 as a function of η in the interval -1.2 $\div$ 1.2. This result is compatible with previous measurement in the electron channel.

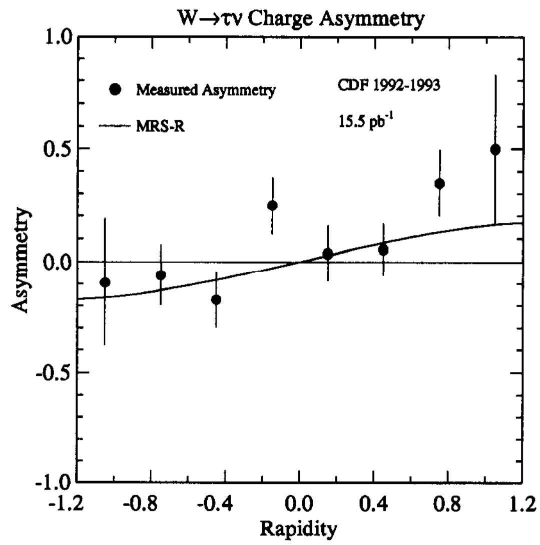

Figure 3: - W$\rightarrow$ $\tau\nu$ charge asymmetry for $-1.2 < \eta < 1.2$.

2 W boson width

2.1 Γ_W indirect measure.

The most precise measurements of Γ_W are extracted from the ratio

$$R = \frac{\sigma_W \cdot B(W \to l\nu)}{\sigma_Z \cdot B(Z \to ll)} = \frac{\sigma_W \cdot \Gamma(W \to l\nu) \cdot \Gamma_Z}{\sigma_Z \cdot \Gamma(Z \to ll) \cdot \Gamma_W}$$

by using the LEP value of $\Gamma(Z{\rightarrow}ll)/\Gamma_Z$ and the theoretical values of $\Gamma(W{\rightarrow}l\nu)$ and $\sigma(W)/\sigma(Z)$.

The statistical precision with which the R measurements determines the Γ_W is dominated by Z statistics.

D0 and CDF have both performed this measures.

D0 has the more recent results obtained using the electron and muon decay mode to extract the ratio R from the run Ib data. The quoted preliminary value of R is

$$R = 10.48 \pm 0.43$$

and the computed W full width is

$$\Gamma_W = 2.126 \pm 0.092 \text{ GeV}$$

CDF published results are obtained from run Ia data. The Γ_W was determined to be

$$\Gamma_W = 2.064 \pm 0.060 \pm 0.059 \text{ GeV}$$

using the the W$\rightarrow$ $e\nu$ decay mode to determine the value of R. The same analysis for the run Ib is currently underway.

2.2 Γ_W direct measure.

The Γ_W can be measured directly from the $M_T(e,\nu)$ lineshape fitting the $M_T \gg M_W$ region where the shape is sensitive to the Γ_W and relatively insensitive to the systematic uncertainties in the detector resolution.

The direct measure complements the standard R measurement in several ways:

- theoretical input for $\sigma(W)/\sigma(Z)$ and $\Gamma(W \to e\nu)$ are not needed;
- sources of systematic errors are different;
- advantage in having more than one method of measuring a given particle property.

CDF has preliminary results on the direct mesurement of Γ_W based on run Ib electron data. A trigger requiring events with high E_t central electrons is used. The following detailed cuts are imposed by the event selection:

- central electron with $E_t > 25$ GeV;
- associated track $p_t > 15$ GeV/c;
- $|z_o| < 60$ cm;
- $|z_o + 130cm \cdot \cot\theta| < 150$ cm;
- $|\vec{u}| < 20$ GeV;
- $|\vec{\not{E}}_t| > 25$ GeV;
- $|d_{beam}| < 0.5$ cm;
- Z $\to$ ee removal;
- Had/EM(3 towers) $< 0.55 + 0.045 \cdot E/100$ GeV;
- $|\Delta z(CES, trk)| < 5$ cm;
- track isolation cut.

Here the vector $\vec{u}$ is the vector sum of calorimeter transverse energies with the lepton energy subtracted and the underlying event energy added. The $\vec{\not{E}}_t$ is $\vec{\not{E}}_t = (\vec{E}_t + \vec{u})$.
Track isolation cut means $N_{cone} = 0$, where N_{cone}, the track isolation variable, is the number of tracks of $p_t > 1$ GeV/c in a $\Delta R < 0.25$ around the electron track.
The $M_T(e,\nu)$ lineshape is modeled going through the following lines:

- generate the W boson with correct distributions (mass, p_l^W, p_t^W and polarization);
- decay the W properly;
- model the spread in z of $\bar{p}p$ collisions;
- simulate the calorimeter response to e, γ and recoiling hadrons;
- model the kinematic and geometric acceptance cuts;
- estimate the size and M_T shape of the important background processes.

The background from W$\rightarrow \tau\nu \rightarrow e\nu\nu\nu$ is calculated with Monte Carlo simulation. The Z$\rightarrow ee$ background, given by Z$\rightarrow ee$ events in which one of the electrons escapes the detector, is strongly suppressed by the $\vec{u} < 20$ GeV and $\not{E}_t$>25 GeV requirements. It is again evaluated by simple Monte Carlo simulation. The QCD dijet background events are estimated analysing the N_{cone} distribution in a electron plus dijet data sample.
The fit of the M_T lineshape proceeds along the following steps:

- simulation of M_T spectra templates for various Γ_W;
- normalization of each signal template to the 47370 events [48765-1395(background)] in the M_T range 40-200 GeV;
- performing a binned likelihood fit in the M_T region 110-200 GeV;
- fitting a third-order polynomial to -2log(L) vs Γ_W.

The fit result is shown in fig.4, where the data points with the best fit overlayed are plotted in logarithmic scale (bottom) and in linear scale (top). The size and shape of the summed backgrounds are also shown.

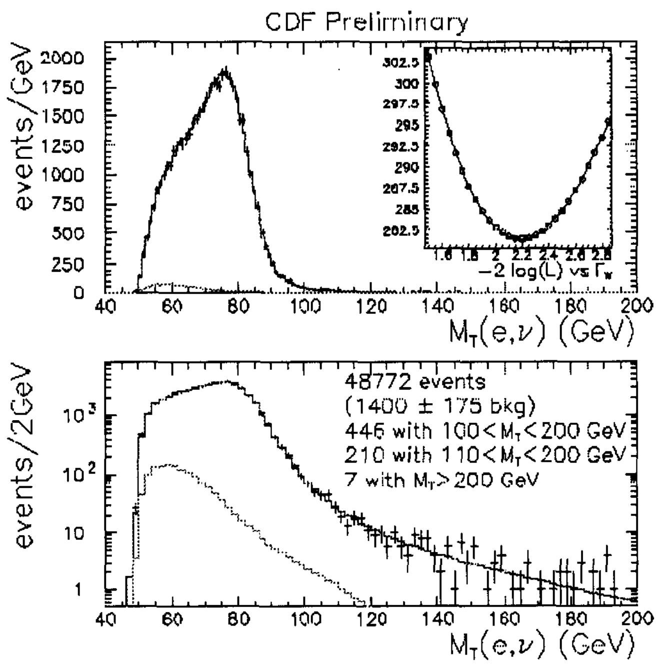

Figure 4: - The M_T^W distribution with the best fit overlayed in logaritmic scale (bottom) and in linear scale (top). The size and shape of the summed background are also shown.

The final result obtained in the above M_T region is:

$$\Gamma_W = 2.19^{+0.17}_{-0.16}(stat) \pm 0.09(syst) \text{ GeV}$$

3 Summary

Both the experiments CDF and D0 are still working to complete the analyses of the W boson properties with all the data collected at the Tevatron Collider during the run 1. The more recent results obtained studing the channel W$\rightarrow \tau\nu$ are the following.

- The D0 measurements of $\sigma_W \cdot B(W \to \tau\nu)$ and g_τ/g_e with a $\mathcal{L}_I = 17\ \mathrm{pb}^{-1}$. These give:

$$\sigma_W \cdot B(W \to \tau\nu) = 2.38 \pm 0.09 \pm 0.10 \pm 0.13\ \mathrm{nb}$$

$$g_\tau/g_e = 1.004 \pm 0.019(stat) \pm 0.026(syst)$$

- The CDF first preliminary results on g_τ/g_e from W$\to \tau\nu$, $\tau \to\ e\nu\nu$ from the run Ib data.

$$g_\tau/g_e = 1.01 \pm 0.17(stat) \pm 0.09(syst)$$

- The preliminary results on W$\to \tau\nu$ asymmetry from CDF ($\mathcal{L}_I \sim 15.5\ \mathrm{pb}^{-1}$)
- D0 has preliminary results on the indirect measurement of the W boson width performed with the run Ib data. The obtained value is:

$$\Gamma_W = 2.126 \pm 0.092\ \mathrm{GeV}$$

  The same measure for run Ib is currently under analysis for CDF.
- CDF presents a preliminary result on the direct measure of Γ_W for run Ib which is:

$$\Gamma_W = 2.19 \pm 0.17(stat) \pm 0.09(syst)\ \mathrm{GeV}$$

With the above results, the current average value for the Γ_W from Hadron Colliders is:

$$\Gamma_W = 2.062 \pm 0.059\ \mathrm{GeV}$$

To be compared with the standard model expectation:

$$\Gamma_W = 2.077 \pm 0.014\ \mathrm{GeV}$$

References

[1] F.Abe et al., CDF Collaboration:Phys.Rev.Lett., 68,3398,(1992).